



# **NDE Process Development Specification for SRB Composite Nose Cap**

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## **TECHNICAL MEMORANDUM**

### **NDE PROCESS DEVELOPMENT SPECIFICATION FOR SRB COMPOSITE NOSE CAP**

#### **I. SCOPE**

##### **A. Purpose**

This process specification outlines the application of nondestructive evaluation (NDE) to the characterization, inspection, and compliance of the composite system to be used in the new Solid Rocket Booster (SRB) Composite Nose Cap (CNC) program. These applications are to be used solely in the material characterization, prototype, and qualification phases of this program. The NDE's called out in this specification, and their particular applications, in no way dictate or recommend the final NDE to be used by the manufacturing vendor in the production phase. If the vendor can provide similar assurances to the integrity of the composite system, then this specification is satisfied.

##### **B. Acceptance Criteria**

The acceptance criteria for this composite system are defined by engineering drawing. With NDE, chemical/physical, and metallurgical investigations, acceptance criteria may be established. In the External Tank (ET) program, a 2-in.<sup>2</sup> area laminar flaw was defined as critical in the CNC program. In the SRB CNC program, unlike the single laminate structure in the ET program, we have not only delaminations to worry about, but debonds between the sandwich structure components and insulation foam anomalies that are rare but could occur, should process controls fail. Thus, much work and thought needs to be done to determine meaningful acceptance limits.

##### **C. Requirements Definition**

Personnel, materials, and facilities requirements are defined by this specification.

#### **II. BACKGROUND**

##### **A. Introduction**

The inherent complexity of composites have made it difficult to predict their performance in aerospace applications. This has also made the verification of their integrity a paramount task. Areas of concern include delaminations, excessive porosity, voids, broken fibers and tows, matrix cracking, debonds, wrinkles, shrinkage, etc. Historically, x rays and ultrasonics have provided some success in the

detection of these anomalies, but only above certain thresholds. Also, these two methods have a disadvantage of being very laborious, and/or very costly, even if automated. Film placement and alignment are critical. Handheld or manual ultrasonic inspection (UI) is very labor intensive. However, with the advent of faster and more efficient data acquisition systems, ultrasonics has branched out into other methods such as resonance testing. Also, infrared thermography has benefited from this computer revolution. Faster flash heating lamps make it possible to screen composites for a myriad of anomalies without extensive tooling and manpower requirements. Frame-grabbing critical heat flow images enable the thermographic inspector to quickly detect many types of defects. We have used this method as an effective initial screening tool and then have used contact ultrasound as a backup referee method. X-ray inspection has also been used to verify ambiguous results from both of those methods.

### **B. Infrared Thermography**

The basic principle of thermal inspection involves the measurement or mapping of surface temperatures when heat flows from, to, or through a test object. Temperature differentials on a surface, or changes in surface temperature with time, are related to heat flow patterns and can be used to detect flaws or to determine the heat transfer characteristics of a test body. An example would be a hot spot generated when an adhesive-bonded panel is uniformly heated on one side. A localized debonding between the surface being heated and the substructure would hinder heat flow to the substructure and thus cause a temperature anomaly when compared to the rest of the surface. Generally, the larger the imperfection and the closer it is to the surface, the greater the temperature differential.<sup>1</sup>

### **C. Conventional X Ray**

Radiography (most often referred to as x ray) is the general term given to material inspection methods that are based on the differential absorption of penetrating radiation, either electromagnetic radiation—of very short wavelength, or particulate radiation—by the part or test piece (object) being inspected. Because of differences in density and variations in thickness of the part or differences in absorption characteristics caused by variations in composition, different portions of a test piece absorb different amounts of penetrating radiation. These variations in the absorption of the penetrating radiation can be monitored by detecting the unabsorbed radiation that passes through the test piece. In general, radiography can detect only those features that have an appreciable thickness in a direction parallel to the radiation beam. This means that the ability of the process to detect planar discontinuities such as cracks depends on proper orientation of the test piece during inspection. Discontinuities such as voids and inclusions, which have measurable thickness in all directions, can be detected as long as they are not too small in relation to section thickness. In general, features that exhibit a 1-percent or more difference in absorption compared to the surrounding material can be detected.<sup>1</sup>

### **D. Ultrasonics**

Ultrasonic inspection is a nondestructive method in which beams of high frequency sound waves are introduced into materials for the detection of surface and subsurface flaws in the material. The sound waves travel through the material with some attendant loss of energy (attenuation) and are reflected at interfaces. The reflected beam is displayed and then analyzed to define the presence and location of flaws or discontinuities.<sup>1</sup>

## **1. Resonant Inspection Technique**

The ultrasonic contact probe is driven at its resonant frequency and placed on the sample with couplant. The electrical impedance changes in the sensor are analyzed to detect the unbonds. This mode works well for many unbonds and delaminated materials.<sup>2</sup>

## **2. Pitch-Catch Swept Frequency**

This method uses a dual-element, point contact, noncouplant, low-frequency ultrasonic probe. One element transmits acoustic waves into the test part and a separate element receives the sound propagated in a plate wave mode across the test piece between the probe tips. The return signals are processed and the difference between the effects of good and bad bonds on the sound path are detected. The frequency is swept over a range.<sup>2</sup>

## **3. Mechanical Impedance**

This method uses a single-tipped, dual-element probe. A drive element generates audible sound waves and the receive element detects the effect of test piece bond variations on probe loading. During setup, the drive frequency is swept through the range of 2.5 to 10 kHz to establish the test frequency. Testing is then performed at a fixed frequency. This mode does not require a couplant and has a small contact area so it can be used on irregular or curved surfaces.<sup>2</sup>

# **III. APPLICABLE DOCUMENTS**

The latest revisions or revisions that are in effect at the time of implementation are as follows:

- MSFC-P18.1-C02 Personnel Certification for Nondestructive Evaluation.
- EH13-OWI-004B Contact Ultrasonic Inspection.
- EH13-OWI-005B Immersion Ultrasonic Inspection.
- JPL-FS515881 Detail Specification for Using Ultrasonics of Materials.
- EH13-OWI-012A Thermographic Inspection.
- EH13-OWI-011B Radiographic Inspection.
- EH13-OWI-020A NDE Document Data Control.

# **IV. PROCESS REQUIREMENTS**

## **A. Written Procedures**

All inspections shall be performed in accordance with a detailed written procedure. The procedure shall meet the requirements of this specification and include the following:

- Reference to this specification by number and title.
- Reference to appropriate Marshall Space Flight Center (MSFC) OWI by number and title, for work performed at MSFC.

- Manufacturer and model numbers of all instrumentation.
- Description of scanning equipment and method for determining scan speeds and indexes, if applicable.
- Description of couplant or coupling devices, as applicable.
- For ultrasonics, infrared thermography and radiography, record all pertinent data so that any level II personnel (dictated by MSFC-P.18.1-C02 for MSFC onsite inspection) can duplicate setup exactly. Outside MSFC, ASNT TC1A will define the level II requirements.
- Description of scanning equipment and method for determining scan speeds and indexes, if applicable.
- Scan plan.
- Description of calibration procedure and reference standards.
- Anomaly evaluation procedure.

## **B. Inspection Method**

A pulse-echo, contact, impulse, or resonant ultrasonic method has been proposed for primary inspection. During the characterization and prototype phases at MSFC, immersion ultrasound will be used also as a primary, automated technique. Also, an automated infrared thermography method with a heating lamp will be used through the prototype stage at MSFC. For selected areas, including the spherical top of the CNC, radiography will also be used by placing film on the inside, with the x-ray source on the outside. All four approaches will be used through completion of the prototype phase. These methods will be used to inspect all configurations of SRB CNC material expected to be tested during these stages leading to the production stage.

## **C. Equipment**

The equipment used shall be capable of performing inspections to the requirements of this specification and to applicable drawings.

## **D. Couplant**

For ultrasound inspections, contact or immersion, demineralized water is recommended to be used because of possible contamination concerns. A water-washable paint may be used for thermographic inspections.

## **E. Reference Standards**

Reference standards with a physical configuration, acoustic properties, thermal characteristics, and density profile similar to the part under test shall be used to establish NDE parameters. Acoustic properties are considered similar when the difference in attenuation between the reference standards and the part is  $\leq \pm 4$  dB. The thickness of the reference standard shall be within 10 percent or 2 plies, whichever is greater, of the thickness of the part. The reference standards shall contain reference flaws representative of the types of defects which must be detected. Reference flaws used to establish the test parameters shall be equal to or smaller than the smallest unacceptable defect.



In the characterization and prototype phase of this program, methods to create the following types of anomalous conditions will be formulated:

1. Disbonds between the outer laminate and syntactic foam core, and between the inner laminate and syntactic foam core will be created either by contamination or absence of material at innermost layer. No inclusions, such as teflon, will be allowed.
2. Delaminations will be simulated by actual absence of material by appropriate cutting methods. No inclusions will be allowed.
3. Fiber/tow breakage and matrix cracking should be simulated.

It is recommended that a full-scale standard be made before the beginning of prototype inspections. This standard will be used to calibrate inspection equipment prior to production inspection.

To facilitate ultrasonic resonance method formulation, 5- by 5-in. square coupons will be manufactured with the baselined material set (see fig. 1) and in the following configurations:

- Outer laminate skin only, in its proper thickness, layup, and cure.
- Inner laminate skin only, in its proper thickness, layup, and cure.
- Outer laminate skin bonded to syntactic foam only.
- Inner laminate skin bonded to syntactic foam only.
- Completely bonded material set.

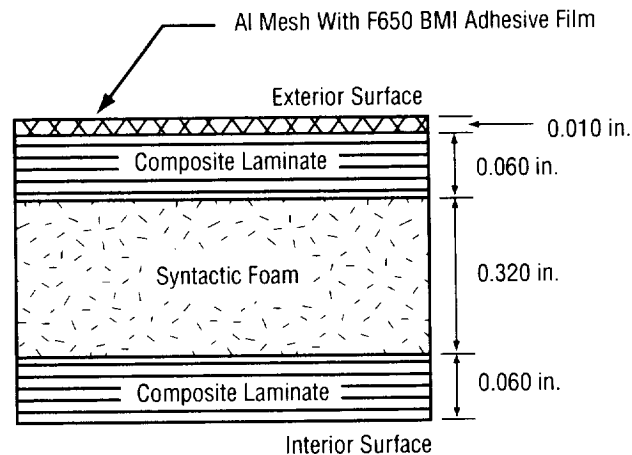


Figure 1. Baselined material set/configuration.

## F. Calibration

In addition to prescribed linearity checks as called out in applicable work instructions, the inspection system shall be calibrated against the appropriate reference standard at the beginning and end of each inspection shift and every 4 hr in between. The system shall also be calibrated after any power interruption or system shutdown and before scanning any part where changes in part thickness of

>10 percent have occurred. A C-scan, for example, of the reference standard clearly showing the relevant reference flaws shall be produced as part of the calibration procedure. All of the calibration records shall be maintained as part of the inspection record.

### **G. Surface Preparation**

The surface of the laminate or the multilayer composite structures under test shall be free of any dirt, oil, or grease which may interfere with the inspection. If a honeycomb core is used in lieu of the syntactic foam, all exposed core areas will be sealed prior to inspection with immersion ultrasonics. All sealing materials added for inspection shall be removed from parts immediately after inspection.

### **H. Scanning Speed and Indexing Increment**

The scanning speed and indexing increment shall not exceed the maximum values which provide for detection of all relevant flaws in the reference standard used to set up the test.

### **I. Coverage**

Unless otherwise specified by the responsible SRB chief engineering authority, all parts shall be 100-percent inspected.

### **J. Scan Plan**

The entire SRB CNC will be inspected. Including with the top (closed portion) of the nose cap, which is a 13.6-in. radius sphere, and down the 75-in. length of the nose cap, 100-percent coverage will be required. A grid will be made and placed on the part (in some fashion) during the inspection process. At the bottom of this half sphere on the top of the nose cap, the axial landmarks should start numbering 1 to 47 (2-in. increments) and there should be 15 circumferential increments (8°). At the middle of the sphere on the top of the nose cap, these increments match the size of the ultrasonic probes used. It also corresponds to the minimum flaw size required in the ET CNC program. For improved resolution, overlapped scanning will be required. Thus, the only purpose for the gridding is to provide a reporting system for showing indication locations from the NDE. After the nose cap is removed from the mold, the entire shell will be inspected. After the machining of the strut holes, a subsequent inspection will be required to verify these areas.

### **K. Equipment Requirements at MSFC During Material Characterization and Prototype Phase**

Flat panel testing will be performed with a five-axis ultrasonic immersion system with 2.25- or 5-MHz, 0.25- or 0.50-in. diameter, piezoceramic transducers in tandem used in a through-transmission technique. Also, an infrared thermography system with flash heating lamps will be used to inspect the panels. In this phase it will also be determined if thermography is indeed suitable as a one-sided inspection method. The syntactic foam in the middle is an insulative layer and may pose problems for heat transfer. The qualification and production inspection method of the SRB CNC is proposed to be contact resonance ultrasound, but we feel that an automated method would be more desirable and would cut down on inspection time by a factor of 10. Thermography is cheaper and easier to automate and has the

ability to find many of the anomalies that ultrasound can find including delaminations, excessive porosity, wrinkles, etc. When needed for further anomaly definition, flat panels will be x rayed with a 320 or 420 KeV source and Kodak film.

In the prototype stage, the full-sized nose cap will be inspected on an automated turntable system which is part of an automated ultrasonic bubble squirter which is located in the southwest side of building 4707 across from room 133. The tooling to mate the SRB CNC to the turntable has been procured. A blanket order agreement with a university has been put in place to support the thermography testing. Also, an ultrasonic resonance test system has been purchased which can emulate the proposed ultrasonic technique for the production cone. Civil service employees will support this inspection technique as well as any x ray required. The x ray will require the cone to be placed in building 4702, room 103, which is a hardened radiation cell.

## **V. REPORTING REQUIREMENTS**

The original NDE results (because of storage size) will be kept in electronic form and be made portable via CD rewritable or Zip100E disks. Test panels and prototype hardware inspections will be input to a work request/shop traveller system administered by EH13 (for work performed at MSFC). The documentation and tracking of this data will follow OWI-EH13-020-A.

## **REFERENCES**

1. *Nondestructive Evaluation and Quality Control*, ASM Handbook, Vol. 17, January 1996.
2. Frederick, C.: *Multi-Mode Adhesive Bond Testing*, 1993 Air Transport Association NDT Forum, Scottsdale Plaza Resort, Scottsdale, Arizona, September 20-23, 1993.

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The Shuttle Upgrade program is a continuing improvement process to enable the Space Shuttle to be an effective space transportation vehicle for the next few decades. The Solid Rocket Booster (SRB), as a component of that system, is currently undergoing such an improvement. Advanced materials, such as composites, have given us a chance to improve performance and to reduce weight.

The SRB Composite Nose Cap (CNC) program aims to replace the current aluminum nose cap, which is coated with a Thermal Protection System and poses a possible debris hazard, with a lighter, stronger, CNC. For the next 2 years, this program will evaluate the design, material selection, properties, and verification of the CNC. This particular process specification cites the methods and techniques for verifying the integrity of such a nose cap with nondestructive evaluation.

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